# Air Pollution Technology Fact Sheet

1. ***Name of Technology**:* Orifice Scrubber

This type of technology is a part of the group of air pollution controls collectively referred to as "wet scrubbers." Orifice scrubbers are also known as self-induced spray scrubbers, gas-induced spray scrubbers, and entrainment scrubbers.

2. ***Type of Technology:*** Removal of air pollutants by inertial and diffusional interception.

3. ***Applicable Pollutants:***

Orifice scrubbers are primarily used to control particulate matter (PM), including particulate matter less than or equal to 10 micrometers (µm) in aerodynamic diameter ($PM_{10}$), particulate matter less than or equal to 2.5 µm in aerodynamic diameter ($PM_{2.5}$), down to particles with an aerodynamic diameter of approximately 2 µm (EPA, 1998).

4. ***Achievable Emission Limits/Reductions:***

Orifice scrubber collection efficiencies range from 80 to 99 percent, depending upon the application and scrubber design. This type of scrubber relies on inertial and diffusional interception for PM collection. Some orifice scrubbers are designed with adjustable orifices to control the velocity of the gas stream (Josephs, 1999; Corbitt, 1990; EPA, 1998; Cooper, 1994).

5. ***Applicable Source Type:*** Point

6. ***Typical Industrial Applications:***

Orifice scrubbers are used in industrial applications including food processing and packaging (cereal, flour, rice, salt, sugar, etc.); pharmaceutical processing and packaging; and the manufacture of chemicals, rubber and plastics, ceramics, and fertilizer. Processes controlled include dryers, cookers, crushing and grinding operations, spraying (pill coating, ceramic glazing), ventilation (bin vents, dumping operations), and material handling (transfer stations, mixing, dumping, packaging). Orifice scrubbers can be built as high-energy units, but most devices are designed for low-energy service (AAF, 1999; Perry, 1984).

7. ***Emission Stream Characteristics:***

   a. ***Air Flow:*** Typical gas flow rates for an orifice scrubber unit are 0.47 to 24 standard cubic meters per second ($sm^3$/sec) (1,000 to 50,000 standard cubic feet per minute (scfm)) (AAF, 1999).

b. ***Temperature:*** In general, orifice scrubbers can treat waste gases up to approximately 150°C (300°F) (Josephs, 1999).

c. ***Pollutant Loading:*** Orifice scrubbers can accept waste flows with PM loadings up to 23 grams per standard cubic meter ($g/sm^3$) or 10 grains per standard cubic foot (gr/scf), or higher, depending upon the nature of the PM being controlled (Josephs, 1999).

### *8. Emission Stream Pretreatment Requirements:*

Orifice scrubbers generally do not require precleaning, unless the waste gas contains large pieces of debris. Precooling may be necessary for high temperature waste gas flows which increase the evaporation of the scrubbing liquid (Josephs, 1999).

### *9. Cost Information:*

The following are cost ranges (expressed in third quarter 1995 dollars) for orifice wet scrubbers of conventional design under typical operating conditions, adapted from EPA cost-estimating spreadsheets (EPA, 1996) and referenced to the volumetric flow rate of the waste stream treated. For purposes of calculating the example cost effectiveness, the pollutant is PM at a loading of approximately 7 $g/sm^3$ (3 gr/scf). The costs do not include costs for post-treatment or disposal of used solvent or waste.

Costs can be higher than in the ranges shown for applications which require expensive materials, solvents, or treatment methods. As a rule, smaller units controlling a low concentration waste stream will be more expensive (per unit volumetric flow rate) than a large unit cleaning a high pollutant load flow (EPA, 1996).

a. ***Capital Cost:*** \$10,000 to \$36,000 per $sm^3$/sec (\$5.00 to \$17 per scfm)

b. ***O & M Cost:*** \$8,000 to \$149,000 per $sm^3$/sec (\$3.80 to \$70 per scfm), annually

c. ***Annualized Cost:*** \$9,500 to \$154,000 per $sm^3$/sec (\$4.50 to \$73 per scfm), annually

d. ***Cost Effectiveness:*** \$88 to \$1,400 per metric ton (\$80 to \$1,300 per short ton), annualized cost per ton per year of pollutant controlled

### *10. Theory of Operation:*

Orifice scrubbers form a category of gas-atomized spray scrubbers in which a tube or a duct of some other shape forms the gas-liquid contacting zone. The particle-laden gas stream is forced to pass over the surface of a pool of scrubbing liquid at high velocity, entraining it as droplets as it enters an orifice. The gas stream flowing through the orifice atomizes the entrained liquid droplets in essentially the same manner as a venturi scrubber. As the gas velocity and turbulence increases with the passing of the gas through the narrow orifice, the interaction between the PM and atomized liquid droplets also increases. Particulate matter and droplets are then removed from the gas stream by impingement on a series of baffles that the gas stream encounters after exiting the orifice. The collected liquid and PM drain from the baffles back into the liquid pool below the orifice (Perry, 1984; EPA, 1998).

The scrubbing liquid is fed into the pool at the bottom of the scrubber and later recirculated from the entrainment separator baffles by gravity instead of being circulated by a pump as in venturi scrubbers. Many devices using contactor ducts of various shapes are offered commercially. The principal advantage of this scrubber is the elimination of a pump for recirculation of the scrubbing liquid (Perry, 1984; EPA, 1998).

### *11. Advantages/Pros:*

Advantages of orifice scrubbers include (Cooper, 1994):

1. Can handle flammable and explosive dusts with little risk;
2. Can handle mists;
3. Relatively low water recirculation rate;
4. Collection efficiency can be varied;
5. Provides cooling for hot gases; and
6. Corrosive gases and dusts can be neutralized.

### *12. Disadvantages/Cons:*

Disadvantages of orifice scrubbers include (Perry, 1984, Cooper, 1994):

1. Effluent liquid can create water pollution problems;
2. Waste product collected wet;
3. High potential for corrosion problems;
4. Protection against freezing required;
5. Off-gas may require reheating to avoid visible plume;
6. Collected PM may be contaminated, and may not be recyclable; and
7. Disposal of waste sludge may be very expensive.

### *13. Other Considerations:*

For PM applications, wet scrubbers generate waste in the form of a slurry or wet sludge. This creates the need for both wastewater treatment and solid waste disposal. Initially, the slurry is treated to separate the solid waste from the water. The treated water can then be reused or discharged. Once the water is removed, the remaining waste will be in the form of a solid or sludge. If the solid waste is inert and nontoxic, it can generally be landfilled. Hazardous wastes will have more stringent procedures for disposal. In some cases, the solid waste may have value and can be sold or recycled (EPA, 1998).

Orifice scrubbers usually have low liquid demands, since they use the same scrubbing liquid for extended periods of time. Because orifice scrubbers are relatively simple in design and usually have few moving parts, the major maintenance concern is the removal of the sludge which collects at the bottom of the scrubber. Orifice scrubbers rarely drain continually from the bottom because a static pool of scrubbing liquid is needed at all times. Therefore, the sludge is usually removed with a sludge ejector that operates like a conveyer belt. As the sludge settles to the bottom of the scrubber, it lands on the ejector and is conveyed up and out of the scrubber (EPA, 1998).

Orifice scrubbers are relatively simple in design and usually have few moving parts, aside from a fan and possibly an automatic sludge ejector (EPA, 1998; AAF, 1999).

### *14. References:*


AAF, 1999. AAF International, web site http://www.aafintl.com, accessed May 19, 1999.

Cooper, 1994. David Cooper and F. Alley, <u>Air Pollution Control: A Design Approach</u>, 2nd Edition, Waveland Press, Prospect Heights, IL, 1994.

Corbitt, 1990. <u>Standard Handbook of Environmental Engineering</u>, edited by Robert A. Corbitt, McGraw-Hill, New York, NY, 1990.

EPA, 1996. U.S. EPA, Office of Air Quality Planning and Standards, “OAQPS Control Cost Manual,” Fifth Edition, EPA 453/B-96-001, Research Triangle Park, NC February.

EPA, 1998. U.S. EPA, Office of Air Quality Planning and Standards, “Stationary Source Control Techniques Document for Fine Particulate Matter,” EPA-452/R-97-001, Research Triangle Park, NC, October.

Josephs, 1999. Dan Josephs, Wet Equipment Product Manager, AAF International, (502) 637-0313, personal communication with Eric Albright, May 21 and 25, 1999.

Perry, 1984. "Perry's Chemical Engineers' Handbook," edited by Robert Perry and Don Green, 6th Edition, McGraw-Hill, New York, NY, 1984.